Method for Recognizing a Structure to be Applied onto a Substrate with Multiple Cameras, and Device Therefore

The present invention relates to a method for recognizing a structure to be applied onto a substrate with at least two or more cameras in accordance with the generic part of claim 1, and a corresponding apparatus therefore.

For recognizing a structure to be applied onto a substrate, it has been customary to carry out optical measurements, whereby frequently various systems for fully automatic testing of the structure, including adhesive and sealing agent lines, are used for this purpose. For this purpose, multiple video cameras are directed at the structure to be recognized, whereby, in addition, an illumination module serving to generate a contrast-rich camera image is required.

In this context, there is a need for a method for recognizing a structure to be applied onto a substrate for at least two or more cameras, which method is used to monitor an application structure or adhesive line at high accuracy and speed while it is being applied. In order to provide for error-free monitoring with multiple cameras, it is essential to carry out the image analysis of the individual cameras such that the software for evaluation of the recorded images can process this data in a suitable fashion.

Another problem in this context is the line-shaped progression of the adhesive line on the substrate since the adhesive line switches from the monitoring area of one camera to the monitoring area of another camera as a function of the motion of the application facility relative to the substrate.

It is therefore the object of the present invention to provide a method for recognizing a structure to be applied onto a substrate for at least two or more cameras, which method facilitates the monitoring of an application structure and/or adhesive line at high accuracy and speed, in particular during the application of the adhesive line to the substrate.

Moreover, it is an object of the present invention to provide a suitable apparatus for carrying out the method according to the invention.

These objects are met with regard to the method by the features of claim 1 and with regard to the apparatus by the features of claim 14.

In the method according to the invention, the structure to be applied is applied onto the substrate by an application facility and then the structure applied onto the substrate by the application facility is monitored by the cameras such that at least an overlapping area of the cameras is directed at the applied structure, whereby the applied structure, in particular the edges of the adhesive line, is transmitted on a surrounding track, and whereby the surrounding track is predefined such that the applied structure intersects the surrounding track after being applied onto the substrate. The surrounding track thus forms a predetermined and predefined area around the application facility such that the adhesive line can be monitored independent of the travel of the robot and/or application facility and can be analyzed in a simple fashion by means of a software. This allows the application structure and/or adhesive line to be monitored at a high rate while it is being applied onto the substrate, in particular if the cameras are arranged on the application facility such as to be fixed in position.

Moreover, it is advantageous if the surrounding track has a closed form around the application facility for determining the adhesive line, whereby the adhesive line on the surrounding track on the substrate is monitored by means of a projection.

According to one embodiment, the adhesive line on the surrounding track is determined in the form of an essentially circular caliper. A circular caliper of this type facilitates the further processing of the data recorded on the circular caliper by means of a software that can be implemented and processed advantageously due to the simple geometric shape.

According to another embodiment, the adhesive line on the surrounding track is determined essentially in elliptical, polygonal form or as continuous lines.

If the center point or the center of the surrounding track essentially coincides with the site that corresponds to the site projected on the substrate by the application facility with regard to the adhesive line, then the adhesive line always reaches the surrounding track essentially with a uniform distance independent of the travel path in order to be able to monitor even a narrow radius of adhesive application for the determination.

According to an advantageous embodiment of the invention, three cameras around the application facility on the surrounding track monitor the applied structure using one overlapping area to the neighboring camera each. Consequently, the progression of the adhesive line to be monitored in any direction can be monitored simultaneously by one or two cameras.

Advantageously, each camera monitors a part of the surrounding track such the individual parts of the surrounding track of the cameras join with the corresponding overlapping areas to form a continuous surrounding track that progresses around the application facility as monitoring area.

According to an embodiment of the invention, each camera monitors a segment of the surrounding track essentially in the form of a circular line forming a circular caliper. In this context, the angle values of the circular line from 0 to 360° form a global coordinate system, whereby one segment of the circular line with adjacent overlapping areas each is assigned to the images of the individual cameras. This allows errors at the transition from one camera to the next camera to be reduced.

It is particularly advantageous for the angle values of the circular line from 0 to 360° to form a global coordinate system of the individual cameras, whereby a segment of the circular line each is assigned to the images of the individual cameras. As a result, the progression of the adhesive line can be followed by at least one active camera, whereby statements concerning the entire adhesive line as well as its position and/or progression can be made by relatively simple means.

According to a preferred embodiment, a first camera covers a range of angles from -10° to 130°, a second camera a range of angles from 110° to 250°, and a third camera a range of angles from 230° to 10°, in case three cameras are being used.

Moreover, during the progression of the adhesive line, it is advantageous to switch automatically from one camera to the next when the adhesive line progresses from the segment of a circular line of one camera via the overlapping area to the segment of a circular line of a different camera. As a result, it is feasible to reliably follow the progression of the line and/or position of the line, and these are predictable accordingly. Therefore, fully automatic switching between neighboring cameras can occur such that the parameterization times are reduced.

Moreover, it is advantageous if the edge of the adhesive line is determined on a circular line in order to detect the adhesive line around the application facility, at any progression, in a defined area. According to a preferred embodiment, the center of the circular line or of the surrounding track essentially coincides with the site from which the adhesive emanates to form the adhesive line, whereby each camera monitors at least one segment of the circle formed by the circular line.

Errors at the transition from one camera to the next can be reduced by having each camera monitor at least one overlapping area jointly with at least one adjacent camera.

Advantageously, the individual cameras are calibrated in order to assign the angle assignment of the individual cameras according to the circular caliper, whereby in particular a circular arc of the calibrating facility with marker points at 0°, 120°, and 240° for three cameras is used. This allows a global coordinate system to be used with regard to the angle assignment for the individual cameras on the circular caliper around the application facility to simplify the image processing by the software.

According to a preferred embodiment of the invention, only a strip of the camera image is processed by each camera in order to form a sequence of images from the individual strips of the camera images, whereby the closed surrounding track is assembled from the strips of the individual camera images. By processing image

strips to form a sequence of images, the image recording frequency can be increased in line with the data reduction achieved by recording only a strip of the image such that the speed of monitoring of the application structure can be increased.

The present invention provides an apparatus for recognizing a structure to be applied onto a substrate, preferably an adhesive line or adhesive line, for carrying out the method according to the invention according to claims 1 to 13, whereby at least one illumination module and one sensor unit are provided. For this purpose, the sensor unit is made up of at least two or more cameras which are provided and arranged around the facility for applying the structure, and each are directed at the facility for applying the structure, whereby at least one overlapping area of the cameras is directed at the applied structure, and whereby the applied structure, in particular the edges of the adhesive line, is determined on a surrounding track around the application facility and whereby the surrounding track is predefined such that the applied structure intersects the surrounding track after being applied onto the substrate. By this means it is feasible for the travel path of the facility over a substrate and/or a travel path of the substrate relative to the application facility to be monitored at all times in all directions by means of directing the cameras at the application facility by means of the surrounding track.

If the axial longitudinal axis of the individual cameras essentially intersects, in the direction of view, the axial longitudinal axis of the application facility, it is advantageous according to a development of this type that a narrow area around the application facility can be monitored at suitable resolution and high image recording rate.

According to a preferred embodiment, individual cameras, in particular 3 cameras, are arranged at equal distances from each other in the direction of the circumference.

Advantageously, the individual cameras are circuited such that the images of the cameras are stored in a sequence of images such that these images can be recorded synchronously and in parallel as well as in an assigned fashion.

For a higher rate of processing of the images recorded by the cameras, it is advantageous for each camera to record only a strip of the image and form a part of the sequence of images.

According to a development of an invention, the cameras form a circular caliper whose center is formed by the application facility of the structure. In this context, one or more circular calipers can be used that facilitate the determination of the edge of the adhesive line on a circular line.

Another advantage consists of each camera monitoring a part of the surrounding track such that the individual parts of the surrounding track plus the overlapping areas form a closed surrounding track that progresses around the application facility in the form of a monitoring area on the substrate.

According to a preferred embodiment, the individual cameras comprise an overlapping area of at least 10° each relative to the next camera. This overlapping area facilitates fully automatic switching between neighboring cameras when the adhesive line progresses from the monitoring area of one camera to the next, since the selection of the camera is not bound to the robot position or a time component, but rather refers to the actual inspection results, i.e. is based on the arrangement on the circular line of the circular caliper and/or the global coordinate system formed thereby.

Moreover, it is of advantage to use a calibrating disc with individual form elements for calibrating the individual cameras for the assignment of the angle assignment, whereby these form elements comprise, in particular, an angle distance of essentially 10°. This allows for assignment of the scaling factor, angle assignment, and center as well as radius of the search circle for the individual cameras. According to the invention, the calibrating disc comprises at least three marker sites that are arranged in a circular arc of the calibrating disc of essentially 0°, 120°, and 240°, in order to calibrate three cameras.

Further advantageous developments of the invention are the subject of the remaining subclaims.

Advantageous developments of the invention shall be illustrated in an exemplary fashion by means of the following drawings.

Figure 1 shows a schematic side view of an apparatus according to the invention for application and monitoring of an adhesive line.

Figure 2 shows a perspective view of the apparatus according to the invention of figure 1.

Figure 3 shows the travel path of the apparatus according to the invention for application and monitoring of an adhesive line.

Figure 4 shows another travel path of the apparatus according to the invention with regard to the switching of the relevant camera.

Figure 5 is a view of a single image composed of three image strips from three cameras for online monitoring.

Figure 6 illustrates the principles of the design of the software.

Figure 7 shows a schematic view of a calibrating device according to the invention for calibrating the individual cameras of the apparatus according to the invention for recognizing a structure to be applied onto a substrate.

Figure 8 shows a schematic view of the adhesive line with the circular caliper and the image strip of the individual cameras.

Figure 9 shows a schematic view of a curved progression of the adhesive line and the monitoring by the circular caliper.

In the following, the design of the apparatus according to the invention for recognizing a structure to be applied onto a substrate is illustrated according to figures 1 and 2.

Reference number 10 indicates the schematically shown apparatus for application and recognition of an adhesive line. In the center of the apparatus according to the invention is arranged an application facility 11 by means of which an adhesive line 20 is applied onto a substrate and/or onto a sheet of metal 30 proceeding from right to left in fig. 1. Three cameras 12, 13, 14 are arranged at equal distances from each other in a circle around the application facility 11, each of which is directed at the application facility 11. As is evident from figure 1, the axial longitudinal axes of the three cameras 12, 13, 14 intersect the axial longitudinal axis of the application facility 11 just below the substrate 30 such that the focus of the individual cameras is arranged right around the area of the application facility 11, in particular on a circular line.

In the inspection of the adhesive, either the application facility with the cameras or the substrate is moved, whereby the adhesive line 20 is simultaneously applied to the substrate 30 by means of the application facility 11, and whereby the cameras 12, 13, 14 monitor the applied structure. For this purpose, it is feasible to move either the application facility with the cameras or the substrate in order to apply the adhesive line onto the substrate 30 such as to follow a desired progression. By this means, the cameras being moved along can monitor, independent of the path of travel, the adhesive line at the time it is being applied. In fig. 2, the adhesive line 20 progresses from left to right and is indicated by a continuous line. The intended progression of the adhesive line 20 is indicated by a dashed line to the right of the application facility 11.

Figure 3 then shows the progression of the adhesive line 20 as indicated by arrows, whereby the direction and/or field of view of the three individual cameras is shown in three sites. The field of view of the three individual cameras each is indicated by a rectangle drawn with a continuous line, a rectangle drawn with widely dashed lines, and a rectangle drawn with narrow dashed lines. As is evident from figure 3, the direction of the individual fields of view of the cameras remains constant at all times whereby only the whole apparatus is moved.

Figure 4 shows another progression of an adhesive line 20, whereby it is indicated in each case, which field of view is active, i.e. which camera having the corresponding field of view shown as a rectangle is active while traveling along the adhesive line. In this context, it must be noted that, on the one hand, only one camera is active at one site, and, on the other hand, two cameras are active at another site. This depends on the progression of the adhesive line relative to the circular caliper to be described below that is used to monitor the adhesive line on the substrate.

Figure 5 then shows three image strips which each represent a relevant section and/or strip of image of the three individual cameras of figure 1. According to the method of the invention, each camera can record just a strip of the image in order to reduce the amount of data accordingly such that the recording rate can be increased. These individual image strips of the three cameras are then joined into an image, whereby the image recording occurs at defined fixed time intervals and independent of the robot control of the application facility. For example, the cameras only record a strip of the image, whereby instead of an image height of 480 pixels an image height of approx. 100 pixels (100 image lines) is used. By means of this partial scanning technique, i.e. partial reading-out of the image recording chip, only small data streams are generated such that the image recording rate can be increased several-fold accordingly. It is therefore feasible in the data analysis to capture the images of the individual cameras synchronously and in parallel and therefore simultaneously and then join them into a single image, whereby the three image strips are arranged one below the other. As a result, the three images, i.e. the three image strips, are correctly arranged and assigned with regard to location and time relative to each other without further ado, and can be processed accordingly. This specific image recording technique therefore facilitates simultaneous and parallel recording of individual camera images, whereby it becomes feasible to scan this structure just once during the teach-in of a reference application structure, whereby the images of all cameras are stored in a sequence of images.

Once the images of the three cameras are stored in a sequence of images, a parameterization of this reference track is carried out as the subsequent step of teaching-in the reference adhesive line. The robot travel path, robot travel time, direction, width, and quality of the adhesive line are used in the parameterization.

This results in a type of vector chain for the adhesive line which allows to attain the high image recording rate and comparably short partial sections (between 1 and 3 mm). Vectorization has another advantage in that the adhesive line, being in the form of a vector chain, can be stored in a camera-transcending global coordinate system.

As is evident from the bottom strip of figure 5, a caliper for gray scale value scanning is arranged around the center of the application facility 11 in the form of a circular line, whereby the two edge points 21 and 22 of the adhesive line 20 are arranged on the circular line. This circular line is subdivided such that a range of angles from -10° to 130° is assigned to a first camera, a range of angles from 110° to 250° is assigned to a second camera, and a range of angles from 230° to –10° is assigned to a third camera such that gapless coverage around the application facility 11 by overlapping areas of the individual cameras is facilitated. From this results a global coordinate system for the three image strips that can be provided to be Cartesian or polar.

If the adhesive line progresses out of the field of view of a camera, the adhesive line is transiently in the overlapping area of the ranges of angles of the two cameras. If the adhesive line then progresses from the segment of the circular line of the one camera via the overlapping area to the segment of the circular line of another camera, an automatic switch is made from the one to the other camera. This is shown, in particular, in figure 4 by means of the active fields of view of the individual cameras.

The advantages mentioned above are attained by the individual cameras forming a circular caliper whose center is formed by the application facility 11, whereby the search for the edges 21, 22 of the adhesive line on a circular line proceeds directly around the application facility. For this purpose, it is essential that the individual cameras are directed at the application facility, whereby the axial longitudinal axes of the individual cameras intersect the longitudinal axis of the application facility. In particular the width of the pair of edges, of the right and the left edge of the adhesive line, the mean gray scale value of the projected gray scale value profile between the pair of edges, the edge contrast, and the progression of the position are included in the calculation by means of an assessment function in the software.

A teach-in run and/or a teach-in of a reference adhesive line is illustrated in the following.

The teach-in process of the reference adhesive line can be started by the user by means of a mouse click on the line which indicates the position of the adhesive line. This is sufficient for fully automatic recognition of position and direction of the adhesive line in the subsequent camera images, since the image recording rate is sufficiently high and the individual images are recorded very shortly after one another, for example every 1 mm to 3 mm. From the starting point, the adhesive is scanned image by image, whereby the adhesive line position and the adhesive line angle detected in the current image are used for the upcoming image as a priori knowledge. The fact that the track radii usually exceed 20 mm facilitates fully automatic capture of the adhesive line without a human being having to determine and/or assess the image and/or the position of the adhesive line. As a result, the search area can be limited which allows, by means of the high image recording rate, to calculate where the adhesive line will essentially progress in the following image.

Figure 6 shows the principles of the design of the software, whereby the teach-in run and/or teaching-in run generates the image sequence, which in turn facilitates the automatic parameterization. This parameterization can be pre-set by the user, if applicable, and is used jointly with a progression file for inspection of an applied adhesive line during the inspection run.

The online monitoring of an applied adhesive line shall be illustrated briefly in the following. The application facility 11 shown in figure 1 applies the adhesive line onto the metal sheet 30, whereby the application facility 11 is moved jointly with the cameras over the metal sheet 30. However, a kinematic inversion is also feasible, i.e. the metal sheet 30 being moved and the application facility with the cameras being arranged to be fixed in position. The applied adhesive line 20 is determined and analyzed synchronously and in parallel by the cameras 12, 13, 14 on the circular line of the circular caliper illustrated according to figure 5, whereby each camera records only a strip of the image and joins these into a single image to form a sequence of images. The image recording rate is increased in accordance with the data reduction attained by each camera recording only a strip of the image, whereby the individual

image strips in the joint image facilitate the synchronous and parallel as well as simultaneous capture of the three camera images, and whereby the individual images of the three cameras can be assigned directly as a function of location. As a result, online monitoring of the adhesive line in real-time is feasible that achieves high accuracy at high travel speeds due to the high image recording rate both in teaching-in a reference adhesive line and in the inspection of the applied adhesive line. In this context, the information concerning the adhesive line in the adhesive search area, the angle assignment of the sensor, the adhesive assessment, the robot travel path, and the robot travel time are summarized in a progression list.

According to an embodiment of the present invention, an assessment function, in particular a fuzzy assessment, can be used to find the edges of the adhesive line. In order to determine and assess the adhesive line, the following parameters are included in the calculation of a fuzzy assessment:

Width of the pair of edges (edge 1: left edge of the adhesive line, edge 2: right edge of the adhesive line), mean gray scale value of the projected gray scale value profile between the pair of edges, edge contrast (geometric mean of the amplitudes of the two edges), and progression of position (directed deviation of the center between the two adhesive edges from the center of the search area, in pixels). By means of the plurality of parameters, and the use of the fuzzy assessment function, the adhesive line can be described very accurately such that the adhesive line can be recognized automatically in a reliable fashion.

The illumination module (not shown here) for the apparatus according to the invention is made up of LEDs, in particular infrared LEDs, UV LEDs or RGB LEDs. In order to attain high contrast in image recording, the LEDs can be flashed, i.e. short, strong pulses of current on the order of 1.0 to 0.01 ms can be applied to the diodes. In this context, light-emitting diodes capable of emitting light of various colors are particularly advantageous such that the sensor design can be switched to other types of adhesive and/or colors of adhesives without reconfiguration.

Figure 7 shows a calibration facility 40 in the form of a circular calibrating disc in order to assign to the individual cameras their scaling factor, their angle assignment,

and the center as well as the radius of the search circle. The calibrating disc consists of individual form elements and/or dots 41 that are arranged on a circular line and at an angle distance of essentially 10°. Moreover, marker sites 42 are arranged at equal distance from each other in order to calibrate three cameras. A compensation calculation is used to calculate from the coordinates of the centers of the individual dots, on the one hand, the scaling factors of the individual cameras and, on the other hand, the center as well as radius of the search area. The marker sites at angles of 0°, 120°, 240° in the global coordinate system allow the angle assignment and the corresponding fields of view of the individual cameras to be determined. The field of view of the individual cameras is indicated, in particular, by the three rectangles in figure 7, whereby the form elements 41 can correspond to the circular line of the circular caliper for detection of the adhesive line.

According to an embodiment that is not shown, multiple circular calipers are formed by multiple cameras that are arranged around the application facility, but are attached at different radii from the center of the application facility. For inspection of an application structure and/or adhesive line, the cameras are directed at a circle and/or circular line whose center coincides with the center of the application facility. The optical detection of the adhesive line as illustrated above then proceeds on this circular line.

Figure 8 shows the adhesive line 20 applied onto the substrate by the nozzle of the application facility 11. The circular caliper 90 mentioned above that is provided by the individual cameras to be concentric around the application facility 11 is used in the analysis of the applied adhesive line 20. The dashed rectangles correspond to the image strip of the individual cameras that is used by the software for analysis. In this context, the rectangle 31 is assigned to the first camera as image strip, the rectangle 32 is assigned to the second camera as image strip, and the rectangle 33 is assigned to the third camera as image strip, whereby the individual image strips of the individual cameras each comprise an overlapping area with respect to the neighboring camera. The gray scale value scanning of the circular caliper 90 is carried out by the rectangle 31 of the first camera in figure 8, whereby in particular the edges shown by the small arrows are used for assessment of the quality of the adhesive line, as described above according to figure 5. Accordingly, in the case

shown in figure 8, only the first camera is active according to image strip 31, as illustrated above according to figures 3 and 4. The circular caliper also extends into the overlapping area of the individual image strips 31, 32, 33 such that two neighboring cameras become active in the circle segment of the circular caliper 90 which resides in the overlapping area of 2 image strips 31, 32, and 33, when the adhesive line 20 in this area is shifted and/or progresses due to a track-shaped and/or curved progression, as is indicated schematically by the large arrow in figure 8.

A track-like progression of this type is shown, in particular, in figure 9, whereby the adhesive line in the first position progresses from top to bottom and then progresses towards the right in figure 9, as is indicated schematically by the second position. For reasons of clarity of presentation, figure 9 does not show the entire rectangle 31, 32, and 33 of the individual cameras, but only the straight lines 310, 320, and 330 that are arranged around the application facility 11 such as to be fixed in position, since the cameras are also arranged around the application facility such as to be fixed in position. As a result, the position of the straight lines 310, 320, and 330 does not change upon track-shaped progression of the adhesive line with respect to the application facility 11. Arranged on the circular caliper 90 as indicated by the small arrows, the edges of the adhesive line 20 to be monitored thus are made to migrate from one image strip to another image strip on the circular caliper 90.

In the upper position of figure 9, the adhesive line 20 is on image strip 32 on the caliper 90 as is indicated by straight line 320. The left edge of the adhesive line 20 is in the first position near the straight line 330, whereby only the camera assigned to image strip 32 is active.

If the adhesive line 20 progresses track-shaped, downwards, and towards the right, as shown in figure 9, the left edge of the adhesive line is first to migrate into the monitoring area between the straight line 330 and the straight line 320 such that, as a result thereof, aside from the camera of image strip 32, the camera of image strip 33 also becomes active on the circular caliper 90.

As is shown in the second, lower position of figure 9, both edges of the adhesive line ck are at the end of the track-shaped progression in image strip 33 that is indicated by the straight lines 330. Consequently, only the camera assigned to image strip 330 is still active. Considering the overall progression, a global coordinate system results for the monitoring of the adhesive line 20 due to the circular caliper 90 being arranged around the application facility 11, as indicated by the global coordinate system that is arranged to be constant with regard to the application facility 11. Consequently, the software for assessment of the adhesive line 20 must take into consideration only the progression on the circular caliper 90.

According to an embodiment that is not shown, the circular caliper can also be provided by a surrounding track and/or orbit in essentially elliptical, polygonal form or as continuous lines, for determining the adhesive line by means of gray scale value scanning.

Therefore, a method for recognizing a structure to be applied onto a substrate, preferably an adhesive line, with at least two cameras, in particular three or more cameras, is described, whereby the structure to be applied is applied onto the substrate by an application facility, and whereby the structure applied onto the substrate by the application facility is monitored by the cameras such that at least one overlapping area of the cameras is directed at the applied structure, and whereby the applied structure, in particular the edges of the adhesive line, is determined on a surrounding track around the application facility, and whereby the surrounding track is predefined such that the applied structure intersects the surrounding track after being applied onto the substrate.